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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
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Digital sections and digital line system – Access networks

**Asymmetric digital subscriber line
transceivers 2 (ADSL2)**

ITU-T Recommendation G.992.3

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ITU-T Recommendation G.992.3

Asymmetric digital subscriber line transceivers 2 (ADSL2)

Summary

This Recommendation describes Asymmetric Digital Subscriber Line (ADSL) Transceivers on a metallic twisted pair that allows high-speed data transmission between the network operator end (ATU-C) and the customer end (ATU-R). It defines a variety of frame bearers in conjunction with one of two other services or without underlying service, dependent on the environment:

- 1) ADSL transmission simultaneously on the same pair with voice band service;
- 2) ADSL transmission simultaneously on the same pair with ISDN (Appendix I or II/G.961 [1]) services;
- 3) ADSL transmission without underlying service, optimized for deployment with ADSL over voiceband service in the same binder cable;
- 4) ADSL transmission without underlying service, optimized for deployment with ADSL over ISDN service in the same binder cable.

ADSL transmission on the same pair with voiceband services and operating in an environment with TCM-ISDN (Appendix III/G.961 [1]) services in an adjacent pair, is for further study.

This Recommendation specifies the physical layer characteristics of the Asymmetric Digital Subscriber Line (ADSL) interface to metallic loops.

This Recommendation has been written to help ensure the proper interfacing and interworking of ADSL transmission units at the customer end (ATU-R) and at the network operator end (ATU-C), and also to define the transport capability of the units. Proper operation shall be ensured when these two units are manufactured and provided independently. A single twisted pair of telephone wires is used to connect the ATU-C to the ATU-R. The ADSL transmission units must deal with a variety of wire pair characteristics and typical impairments (e.g., crosstalk and noise).

An ADSL transmission unit can simultaneously convey all of the following: a number of downstream frame bearers, a number of upstream frame bearers, a baseband POTS/ISDN duplex channel, and ADSL line overhead for framing, error control, operations, and maintenance. Systems support a net data rate ranging up to a minimum of 8 Mbit/s downstream and 800 kbit/s upstream. Support of net data rates above 8 Mbit/s downstream and support of net data rates above 800 kbit/s upstream are optional.

This Recommendation includes mandatory requirements, recommendations and options; these are designated by the words "shall", "should" and "may" respectively. The word "will" is used only to designate events that take place under some defined set of circumstances.

This Recommendation defines several optional capabilities and features:

- transport of STM and/or ATM and/or Packets;
- transport of a network timing reference;
- multiple latency paths;
- multiple frame bearers;
- short initialization procedure;
- dynamic rate repartitioning;
- seamless rate adaptation.

It is the intention of this Recommendation to provide, by negotiation during initialization, for U-interface compatibility and interoperability between transceivers complying with this Recommendation and between transceivers that include different combinations of options.

History

This Recommendation describes the second generation of ADSL, based on the first generation ITU-T Rec. G.992.1. It is intended that this Recommendation be implemented in multi-mode devices that support both ITU-T Recs G.992.3 and G.992.1.

This Recommendation has been written to provide additional features, relative to ITU-T Rec. G.992.1. ITU-T Rec. G.992.1 was approved in June 1999. Since then, several potential improvements have been identified in areas such as data rate versus loop reach performance, loop diagnostics, deployment from remote cabinets, spectrum control, power control, robustness against loop impairments and RFI, and operations and maintenance. This Recommendation provides a new ADSL U-interface specification, including the identified improvements, which the ITU-T believes will be most helpful to the ADSL industry.

Relative to ITU-T Rec. G.992.1, the following application-related features have been added:

- Improved application support for an all digital mode of operation and voice over ADSL operation;
- Packet TPS-TC function, in addition to the existing STM and ATM TPS-TC functions;
- Mandatory support of 8 Mbit/s downstream and 800 kbit/s upstream for TPS-TC function #0 and frame bearer #0;
- Support for IMA in the ATM TPS-TC;
- Improved configuration capability for each TPS-TC with configuration of latency, BER and minimum, maximum and reserved data rate.

Relative to ITU-T Rec. G.992.1, the following PMS-TC-related features have been added:

- A more flexible framing, including support for up to 4 frame bearers, 4 latency paths;
- Parameters allowing enhanced configuration of the overhead channel;
- Frame structure with receiver selected coding parameters;
- Frame structure with optimized use of RS coding gain;
- Frame structure with configurable latency and bit error ratio;
- OAM protocol to retrieve more detailed performance monitoring information;
- Enhanced on-line reconfiguration capabilities including dynamic rate repartitioning.

Relative to ITU-T Rec. G.992.1, the following PMD-related features have been added:

- New line diagnostics procedures available for both successful and unsuccessful initialization scenarios, loop characterization and troubleshooting;
- Enhanced on-line reconfiguration capabilities including bitswaps and seamless rate adaptation;
- Optional short initialization sequence for recovery from errors or fast resumption of operation;
- Optional seamless rate adaptation with line rate changes during showtime;
- Improved robustness against bridged taps with receiver determined pilot tone;
- Improved transceiver training with exchange of detailed transmit signal characteristics;
- Improved SNR measurement during channel analysis;
- Subcarrier blackout to allow RFI measurement during initialization and SHOWTIME;
- Improved performance with mandatory support of trellis coding;
- Improved performance with mandatory one-bit constellations;
- Improved performance with data modulated on the pilot tone;
- Improved RFI robustness with receiver determined tone ordering;
- Improved transmit power cutback possibilities at both CO and remote side;
- Improved Initialization with receiver and transmitter controlled duration of initialization states;
- Improved Initialization with receiver-determined carriers for modulation of messages;
- Improved channel identification capability with spectral shaping during Channel Discovery and Transceiver Training;
- Mandatory transmit power reduction to minimize excess margin under management layer control;
- Power saving feature for the central office ATU with new L2 low power state;
- Power saving feature with new L3 idle state;
- Spectrum control with individual tone masking under operator control through CO-MIB;
- Improved conformance testing including increase in data rates for many existing tests.

Through negotiation during initialization, the capability of equipment to support the G.992.3 and/or the G.992.1 Recommendations is identified. For reasons of interoperability, equipment may choose to support both Recommendations, such that it is able to adapt to the operating mode supported by the far-end equipment.

Source

ITU-T Recommendation G.992.3 was approved by ITU-T Study Group 15 (2001-2004) under the ITU-T Recommendation A.8 procedure on 29 July 2003.

It integrates the modifications introduced by ITU-T Rec. G.992.3 (2002) Amendment 1 approved on 22 May 2003.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure e.g. interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementors are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database.

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7.5 Control parameters

The configuration of the PMS-TC function is controlled by a set of control parameters displayed in Table 7-6.

Table 7-6/G.992.3 – Framing Parameters

Parameter	Definition
MSG_{min}	The minimum rate of the message based overhead that shall be maintained by the ATU. MSG_{min} is expressed in bits per second.
MSG_{max}	The maximum rate of the message based overhead that shall be allowed by the ATU. MSG_{max} is expressed in bits per second.
N_{BC}	See Table 6-1. This is a TPS-TC configuration parameter repeated here for clarity.
N_{LP}	The number of latency paths enabled to transport frame bearers and overhead. The latency path functions are labeled #0, #1, #2 and #3.
MSG_{LP}	The label of the latency path used to transport the message based overhead information.
MSG_C	The number of octets in the message based portion of the overhead structure.
$B_{p,n}$	The nominal number of octets from frame bearer # n per Mux Data Frame at Reference Point A in latency path function # p . When T_p is not set to 1 and n is the lowest index of the frame bearers assigned to latency path # p , the number of octets from the frame bearer # n in the latency path function # p varies between $B_{p,n}$ and $B_{p,n} + 1$.
M_p	The number of Mux Data Frames per FEC Data Frame in latency path function # p .
T_p	The ratio of the number of Mux Data Frames to the number of sync octets in the latency path function # p . A sync octet is inserted with every T_p -th Mux Data Frame. When T_p is not set to one, an extra frame bearer octet is carried whenever a sync octet is not inserted.
R_p	The number of RS redundancy octets per codeword in latency path function # p . This is also the number of redundancy octet per FEC Data Frame in the latency path function # p .
D_p	The interleaving depth in the latency path function # p .
L_p	The number of bits from the latency path function # p included per PMD.Bits.confirm primitive.

The first two control parameters listed in Table 7-6 establish persistent constraints upon the operation of the PMS-TC function that apply during all initialization and reconfiguration procedures. The values of these control parameters shall be set during the G.994.1 phase of initialization, in accordance with common requirements of the ATU devices. The requirements for these control parameters by each ATU in each direction may also be exchanged during the G.994.1 phase of initialization.

The remaining control parameters listed in Table 7-6 establish the specific parameters that control the PMS-TC procedures described in this clause. The values of these control parameters shall be set during the PMD initialization procedure in accordance with capabilities of each ATU and requirements of each ATU's higher layers as determined by TPS-TC initialization procedures. Additionally, some of the control parameters in Table 7-6 may be modified during on-line reconfiguration procedures.

All valid control parameter configurations are described in 7.6.2. All mandatory control parameter configurations described in 7.6.3 shall be supported by each ATU.

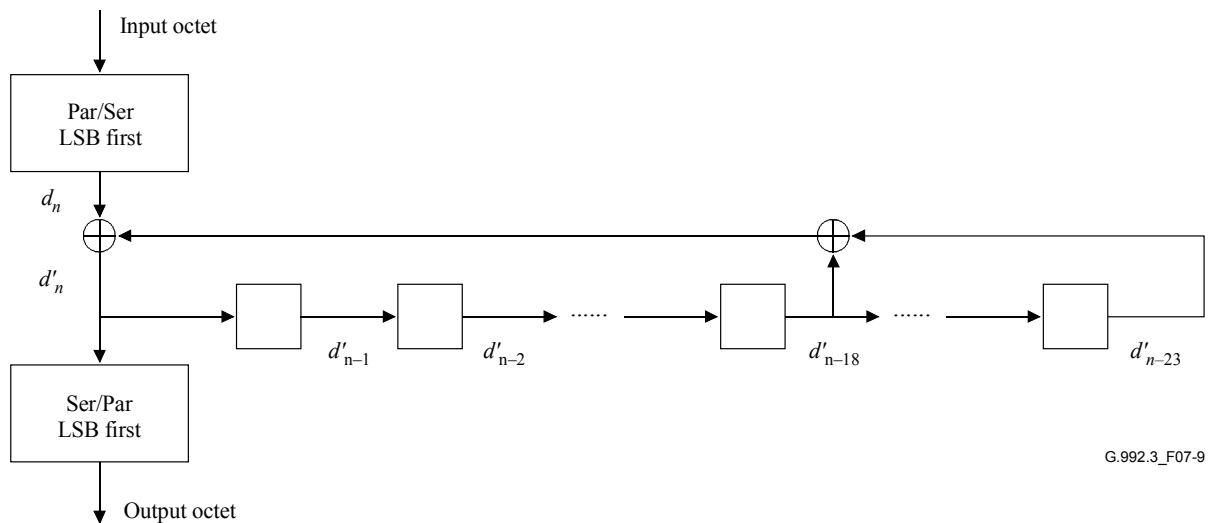


Figure 7-9/G.992.3 – Scrambler procedure

7.7.1.4 Forward error correction function

The FEC procedure inserts Reed-Solomon FEC redundancy octets to provide coding gain as an outer coding function to the PMD function. The FEC procedure of latency path function # p shall calculate R_p octets from $M_p \times K_p$ input octets. The octets are appended to the end of the input octets in the structure of FEC Output Data Frame at Reference Point B.

When $R_p = 0$, no redundancy octets are appended and the values in the FEC Output Data Frame are identical to the input values. For all other values of R_p , the following encoding procedure shall be used to create the R_p octets:

The FEC procedure shall take in M_p scrambled Mux Data Frames comprising message octets, $m_0, m_1, \dots, m_{M_p \times K_p - 2}, m_{M_p \times K_p - 1}$. The procedure shall produce R_p redundancy octets $c_0, c_1, \dots, c_{R_p - 2}, c_{R_p - 1}$. These two taken together comprise the FEC codeword of size $M_p \times K_p + R_p$ octets. The R_p redundancy octets shall be appended to the message octets to form the FEC Output Data Frame at Reference Point B.

At the end of the initialization sequence, the FEC Function always starts with the first of M_p Mux Data Frames.

The redundancy octets are computed from the message octets using the equation:

$$C(D) = M(D)D^{R_p} \text{ modulo } G(D)$$

where:

$M(D) = m_0 D^{M_p \times K_p - 1} + m_1 D^{M_p \times K_p - 2} + \dots + m_{M_p \times K_p - 2} D + m_{M_p \times K_p - 1}$ is the message polynomial,

$C(D) = c_0 D^{R_p - 1} + c_1 D^{R_p - 2} + \dots + c_{R_p - 2} D + c_{R_p - 1}$ is the check polynomial, and

$G(D) = \prod (D + \alpha^i)$ is the generator polynomial of the Reed-Solomon code,

where the index of the product runs from $i = 0$ to $R_p - 1$.

That is, $C(D)$ is the remainder obtained from dividing $M(D) D^{R_p}$ by $G(D)$. The arithmetic is performed in the Galois Field $GF(256)$, where α is a primitive element that satisfies the primitive binary polynomial $x^8 + x^4 + x^3 + x^2 + 1$. A data octet ($d_7, d_6, \dots, d_1, d_0$) is identified with the Galois Field element $d_7 \alpha^7 + d_6 \alpha^6 + \dots + d_1 \alpha + d_0$.

The FEC procedure of the latency path # p creates $N_{FEC,p}$ octets in the structure of a FEC Output Data Frame at Reference Point B. This procedure is followed by the interleaver procedure.

7.7.1.5 Interleaver

To spread the Reed-Solomon codeword and therefore reduce the probability of failure of the FEC in the presence of impulse noise, the FEC Output Data Frames shall be convolutionally interleaved. The interleaver creates the Interleaved FEC Output Data Frames at Reference point C, at the output of the latency path function. This procedure is followed by the frame multiplexing procedure.

Convolutional interleaving is defined by the rule (using the currently defined values of the framing control parameters D_p and the derived parameter $N_{FEC,p}$):

Each of the $N_{FEC,p}$ octets $B_0, B_1, \dots, B_{N_{FEC,p}-1}$ in an FEC Output Data Frame is delayed by an amount that varies linearly with the octet index. More precisely, octet B_i (with index i) is delayed by $(D_p - 1) \times i$ octets, where D_p is the interleaver depth.

An example for $N_{FEC,p} = 5$, $D_p = 2$ is shown in Table 7-13, where B_i^j denotes the i -th octet of the j -th FEC Output Data Frame.

Table 7-13/G.992.3 – Convolutional interleaving example for $N_{FEC,p} = 5$, $D_p = 2$

Interleaver input	B_0^j	B_1^j	B_2^j	B_3^j	B_4^j	B_0^{j+1}	B_1^{j+1}	B_2^{j+1}	B_3^{j+1}	B_4^{j+1}
Interleaver output	B_0^j	B_3^{j-1}	B_1^j	B_4^{j-1}	B_2^j	B_0^{j+1}	B_3^j	B_1^{j+1}	B_4^j	B_2^{j+1}

With the above-defined rule, the output octets from the interleaver always occupy distinct time slots when $N_{FEC,p}$ is odd and D_p is a power of 2. When $N_{FEC,p}$ is even, a dummy octet shall be added at the beginning of the codeword at the input to the interleaver. The resultant odd-length codeword is then convolutionally interleaved, and the dummy octet shall then be removed from the output of the interleaver.

The interleaving procedure of the latency path function # p shall interleave a single FEC Output Data Frame, or $M_p \times K_p + R_p$ octets. This procedure is followed by the Frame Multiplexing procedure.

7.7.2 Frame multiplexing

The output signals of all latency paths are multiplexed together to form the output of the PMS-TC function. The frame multiplexing procedure combines bits from each configured latency path in decreasing label order, starting from $p = 3$ down to $p = 0$. L_p bits are taken from each latency path. $L_p = 0$ if latency path # p is not supported or disabled. The bits are taken LSB first. The data is packed into a PMD.Bits.confirm primitive in order of latency path $p = 3$ down to $p = 0$.

7.8 Control plane procedures

7.8.1 NTR transport

An ATU-C may optionally transport an 8 kHz timing marker as NTR to support the transport of a timing reference from voice PSTN access network to equipment located with the ATU-R. The 8 kHz timing marker is provided to the ATU-C as part of the interface at the V reference point. Additionally, if this capability is supported, the local PMD shall provide a PMD sampling clock that is a multiple of 2.208 MHz ± 50 ppm along with an indication of when each overhead message structure (described in 7.8.2.1) begins.

If NTR transport is configured during initialization or reconfiguration of the PMS-TC function, the ATU-C shall generate an 8 kHz local timing reference (LTR) by dividing the PMD sampling clock